11th APCTP-BLTP JINR-PNPI NRC KI-SPbU Joint Workshop
"Modern problems in nuclear and elementary particle physics"
24-28 July, 2017, Petergof, St. Petersburg, Russia

YONGSEOK OH (KYUNGPOOK NATIONAL UNIV. / APCTP)

Nuclear Energy Density Functional and The Nuclear Alpha Decay

KNU KYUNGPOOK NATIONAL UNIVERSITY

APCTP Asia Pacific Center for Theoretical Physics

CONTENTS

Ref.
E. Shin, Y. Lim, C.H. Hyun, Y. Oh, PRC 94, 024320 (2016)
Y. Lim, Y. Oh, PRC 95, 034311 (2017)

PHYSICAL REVIEW C **94**, 024320 (2016)

Nuclear isospin asymmetry in α decay of heavy nuclei

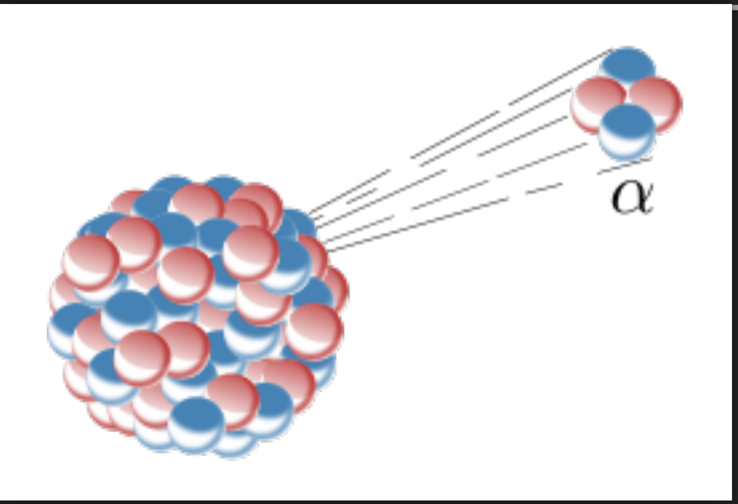
Eunkyoung Shin,[1,*] Yeunhwan Lim,[2,†] Chang Ho Hyun,[3,‡] and Yongseok Oh[1,4,§]
[1]*Department of Physics, Kyungpook National University, Daegu 41566, Korea*
[2]*Rare Isotope Science Project, Institute for Basic Science, Daejeon 34047, Korea*
[3]*Department of Physics Education, Daegu University, Gyeongsan, Gyeongbuk 38453, Korea*
[4]*Asia Pacific Center for Theoretical Physics, Pohang, Gyeongbuk 37673, Korea*
(Received 11 November 2015; revised manuscript received 20 June 2016; published 12 August 2016)

PHYSICAL REVIEW C **95**, 034311 (2017)

Nuclear energy density functional and the nuclear α decay

Yeunhwan Lim[1,*] and Yongseok Oh[2,3,†]
[1]*Cyclotron Institute and Department of Physics and Astronomy, Texas A&M University, College Station, Texas 77843, USA*
[2]*Department of Physics, Kyungpook National University, Daegu 41566, Korea*
[3]*Asia Pacific Center for Theoretical Physics, Pohang, Gyeongbuk 37673, Korea*
(Received 22 January 2017; revised manuscript received 8 February 2017; published 13 March 2017)

INTRODUCTION



- Nuclear α decay:
  the first observed nuclear reaction (1899, Rutherford)
- Why still α decay?
  - A tool to study structure of heavy nuclei
  - Identification of most heavy nucleus formation is made through decays such as α decay chain

Z=118: Oganesson (A=294)

  - E.g.: α decay of (unobserved nucleus) ^{296}Og is planned at JINR @ Dubna.
    (If confirmed, it would be the heaviest element observed so far.)
  - Theoretical understanding of the decay mechanism is needed
    - phenomenological vs fundamental approaches
    - towards more satisfactory theories on the nuclear α decay

THEORIES ON ALPHA DECAYS

- Quantum Tunneling Effects (1928)
  - G. Gamow
  - R.W. Gurney and E.U. Condon
    - one of the first applications of quantum mechanics

Wave Mechanics and Radioactive Disintegration.

AFTER the exponential law in radioactive decay had been discovered in 1902, it soon became clear that the time of disintegration of an atom was independent of the previous history of the atom and depended solely on chance. Since a nuclear particle must be held in the nucleus by an attractive field, we must, in order to explain its ejection, arrange for a spontaneous change from an attractive to a repulsive field. It has hitherto been necessary to postulate some special arbitrary 'instability' of the nucleus; but in the following note

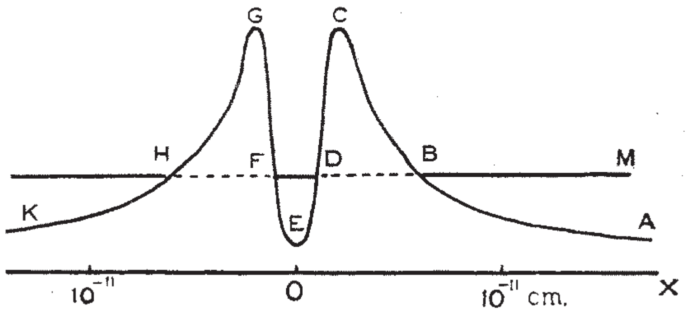


FIG. 1.

RONALD W. GURNEY.
EDW. U. CONDON.
Palmer Physical Laboratory,
Princeton University,
July 30.

Zur Quantentheorie des Atomkernes.

Von **G. Gamow**, z. Zt. in Göttingen.

Mit 5 Abbildungen. (Eingegangen am 2. August 1928.)

Es wird der Versuch gemacht, die Prozesse der α-Ausstrahlung auf Grund der Wellenmechanik näher zu untersuchen und den experimentell festgestellten Zusammenhang zwischen Zerfallskonstante und Energie der α-Partikel theoretisch zu erhalten.

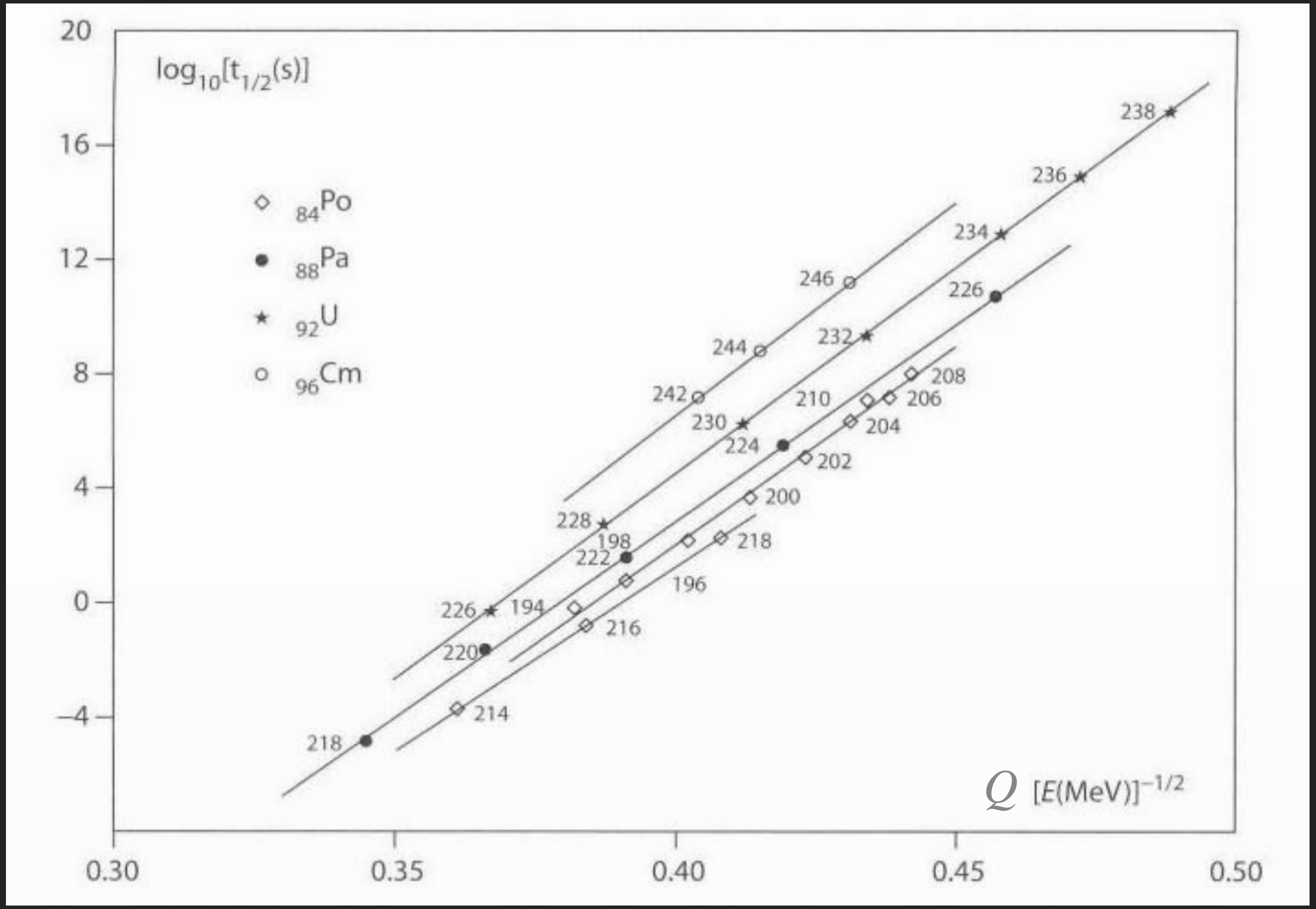
THEORIES ON ALPHA DECAYS

- Geiger-Nuttall law (1911)
  - Viola-Seaborg formula (1961)
  - phenomenological semi-empirical formula

$$\log_{10}(T_{1/2}) = \frac{aZ}{\sqrt{Q_\alpha}} + b$$

$$\log_{10}(T_{1/2}) = \frac{aZ + b}{\sqrt{Q_\alpha}} + cZ + d$$

C. Qi, A.N. Andreyev, M. Huyse, R.J. Liotta, P. Van Duppen, R. Wyss, PLB 734 (2014)



C.A. Bertulani, "Nuclear Physics in a Nutshell" (Princeton Univ. Press, 2007)

BASIS OF ALPHA DECAY THEORIES

- α cluster model
  - the α particle is preformed inside a nucleus.
- Models for effective α potential on nuclear interactions
  - square-well potential, cosh potential, double folding model, etc
- Calculation tool: WKB approximation
  - preformation factor ($\mathcal{P}$)
  - assaulting frequency ($\mathcal{F}$) of the α to the potential well - normalization
  - k: wave number of the α particle

$$T_{1/2} = \frac{\hbar \ln 2}{\Gamma} \qquad \Gamma = \mathcal{P}\mathcal{F}\frac{\hbar^2}{4m}\exp\left[-2\int dr k(r)\right] \qquad k(r) = \sqrt{\frac{2m}{\hbar^2}|Q_\alpha - V(r)|}$$

- Important factors which govern the α decay
  - Q values for the decay process (as can be seen in the GN formula)
    - For example, in $^{212}Po \rightarrow {}^{208}Pb + \alpha$
      - $\delta Q = 0.1$ MeV (where $Q_{exp} \approx 8.95$ MeV) causes a factor of 1.7 difference in lifetime
  - α potential: determined by the nucleon distributions - motivation of the present work
    - the interaction potential between the α particle and the rest of the nucleus (core or daughter nucleus)

α POTENTIALS

$$V = V_N + V_C + V_L$$

V_N : nuclear α potential

V_C : Coulomb potential

V_L : centrifugal potential

The Coulomb potential

$$V_C = 8\pi e^2 \left[\frac{1}{r} \int_0^r \rho_p(r') r'^2 dr' + \int_r^\infty \rho_p(r') r' dr' \right]$$

The centrifugal potential with the Langer modification

$$V_L = \frac{\hbar^2}{2mr^2} \left(\ell + \frac{1}{2} \right)^2$$

ISOSPIN EFFECTS IN NUCLEAR α POTENTIALS

E. Shin, Y. Lim, C.H. Hyun, YO, PRC 94 (2016)

- Effects of isospin asymmetry terms in nuclear α potentials
    - Define: I = (N−Z)/(N+Z),
      where N = neutron number and Z = proton number
    - Square-well potential

$$V_N = \begin{cases} V_0 + V_1 I + V_2 I^2, & r < R \\ 0, & r > R \end{cases}$$

    - Woods-Saxon potential

$$V_N = \frac{V_0 + V_1 I + V_2 I^2}{1 + \exp[(r - R)/a]}$$

    - Viola-Seaborg formula

$$\log_{10}(T_{1/2}) = \frac{aZ + b}{\sqrt{Q_\alpha}} + cZ + d + e_1 I + e_2 I^2$$

EFFECTS OF THE ISOSPIN TERMS 1

Square-well potential

TABLE I. Parameters of the SW potential fitted to the experimental data of Refs. [30,31]. The numbers in parentheses denote the fitted values without the V_1 and V_2 terms. The rms deviation σ is defined in Eq. (6).

Type	Number of events	V_0 (MeV)	V_1 (MeV)	V_2 (MeV)	σ
e-e	178	−140.035 (−132.415)	+57.567	−71.601	0.304 (0.319)
e-o	110	−175.980 (−140.416)	+524.995	−1737.533	0.596 (0.616)
o-e	137	−158.767 (−142.700)	+308.787	−1163.721	0.607 (0.630)
o-o	70	−152.100 (−144.250)	+56.482	−63.256	0.604 (0.609)

Woods-Saxon potential

TABLE IV. Fitted parameters of the WS potential. The notation is the same as in Table I.

Type	V_0 (MeV)	V_1 (MeV)	V_2 (MeV)	σ
e-e	−190.845 (−179.634)	+54.851	+56.370	0.302 (0.326)
e-o	−173.564 (−174.859)	+64.534	−38.600	0.211 (0.212)
o-e	−187.018 (−182.313)	+36.494	+127.714	0.248 (0.251)
o-o	−180.316 (−176.876)	−16.653	+86.544	0.254 (0.256)

EFFECTS OF THE ISOSPIN TERMS 2

Viola-Seaborg Forumla

TABLE VIII. Fitted coefficients of the modified VS formula. The values in parentheses are those of the unmodified VS formula, i.e., without the e_1 and e_2 terms.

Type	a	b	c	d	e_1	e_2	σ
e-e	1.53420 (1.48503)	4.20759 (5.26806)	−0.18124 (−0.18879)	−35.57934 (−33.89407)	5.28401	−38.17144	0.311 (0.359)
e-o	1.64322 (1.55427)	−2.33315 (1.23165)	−0.18749 (−0.18838)	−35.27841 (−34.29805)	1.19898	−31.24030	0.571 (0.608)
o-e	1.69868 (1.64654)	−5.67266 (−3.14939)	−0.22366 (−0.22053)	−32.02953 (−32.74153)	−12.96399	31.01813	0.542 (0.554)
o-o	1.37778 (1.34355)	13.63138 (13.92103)	−0.11009 (−0.12867)	−39.41075 (−37.19944)	5.98423	−52.56801	0.561 (0.617)

Conclusions

- Not a crucial effect on the alpha decay lifetime estimates
- But gives an improvement in RMSD (σ)

α POTENTIAL BASED ON SKYRME FORCE MODEL

- Following the standard Skyrme EDF, we write

$$\begin{aligned} v_{N\alpha}(\boldsymbol{k},\boldsymbol{k}') = & \; s_0\,(1+v_0P_\sigma)\,\delta(\boldsymbol{r}_{N\alpha}) \\ & + \frac{s_1}{2}\,(1+v_1P_\sigma)\left[\delta(\boldsymbol{r}_{N\alpha})\boldsymbol{k}^2 + \boldsymbol{k}'^2\delta(\boldsymbol{r}_{N\alpha})\right] \\ & + s_2\,\boldsymbol{k}'\cdot\delta(\boldsymbol{r}_{N\alpha})\boldsymbol{k} \\ & + iW_0^\alpha\boldsymbol{k}'\cdot(\boldsymbol{\sigma}\times\boldsymbol{k})\,\delta(\boldsymbol{r}_{N\alpha}) \\ & + \frac{s_3}{6}\,(1+v_3P_\sigma)\,\rho_N^\epsilon\delta(\boldsymbol{r}_{N\alpha}) \end{aligned}$$

- This leads to the form of the α potential in terms of nucleon densities as

$$V_N = \alpha\rho_N + \beta\left(\rho_n^{5/3} + \rho_p^{5/3}\right) + \gamma\rho_N^\epsilon\left(\rho_N^2 + 2\rho_n\rho_p\right) + \delta\frac{\rho_N'}{r} + \eta\rho_N''$$

where

$$\rho_N = \rho_p + \rho_n, \quad \rho_N' = d\rho_N/dr, \quad \rho_N'' = d^2\rho_N/dr^2$$

$$\rho_{p,n} = \frac{\rho_{p,n}^0}{1+\exp[(r-R_{p,n})/a_{p,n}]}$$

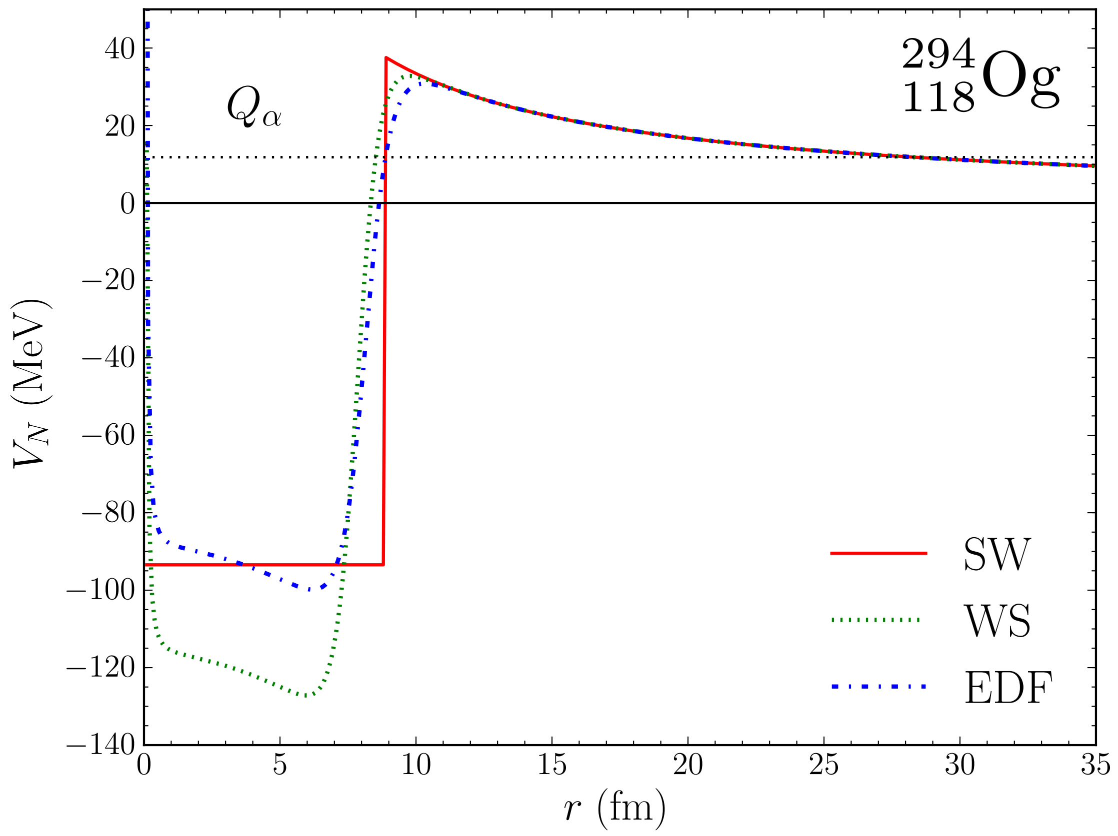
RESULTS

TABLE VII. Fitted parameters of the α-particle potential model based on the Skyrme EDF.

α (MeV fm^3)	β (MeV fm^5)	γ (MeV fm$^{6+3\epsilon}$)	δ (MeV fm^5)	η (MeV fm^5)
-1.6740×10^3	1.9208×10^3	1.7182×10^3	9.4166	-26.7616
σ(e-e)	σ(e-o)	σ(o-e)	σ(o-o)	σ(All)
0.319	0.276	0.283	0.301	0.296

$\epsilon = 1/6$

Better description than simple potential models



$$Q_\alpha^{\rm exp} = 11.81 \text{ MeV}$$

$$T_{1/2}^{\rm SW} = 1.46 \times 10^{-4} \text{ s}$$
$$T_{1/2}^{\rm WS} = 1.26 \times 10^{-4} \text{ s}$$
$$T_{1/2}^{\rm EDF} = 0.40 \times 10^{-4} \text{ s}$$
$$T_{1/2}^{\rm VS} = 0.31 \times 10^{-4} \text{ s}$$

exp: ~ 0.89 ms

α nuclear potential of the three potential models

RESULTS

TABLE XI. Results for α-decay half-lives of heavy nuclei. The upper and lower bounds of theoretical calculations are from the experimental errors of Q_α values.

(Z,A)	$Q_\alpha^{\text{Expt.}}$ (MeV)	$T_{1/2}^{\text{Expt.}}$	$T_{1/2}^{\text{SW}}$	$T_{1/2}^{\text{WS}}$	$T_{1/2}^{\text{EDF}}$	$T_{1/2}^{\text{VS}}$	References
(118,294)	11.81 ± 0.06	$0.89^{+1.07}_{-0.31}$ ms	$1.46^{+0.51}_{-0.38}$ ms	$1.26^{+0.45}_{-0.33}$ ms	$0.40^{+0.15}_{-0.11}$ ms	$0.31^{+0.12}_{-0.08}$ ms	[39]
(116,293)	10.67 ± 0.06	53^{+62}_{-19} ms	163^{+69}_{-48} ms	104^{+44}_{-31} ms	52^{+23}_{-16} ms	181^{+84}_{-57} ms	[40]
(116,292)	10.80 ± 0.07	18^{+16}_{-6} ms	78^{+39}_{-26} ms	69^{+35}_{-23} ms	25^{+13}_{-8} ms	20^{+10}_{-7} ms	[40]
(116,291)	10.89 ± 0.07	$6.3^{+11.6}_{-2.5}$ ms	47^{+23}_{-15} ms	31^{+15}_{-10} ms	16^{+8}_{-5} ms	46^{+25}_{-16} ms	[39]
(116,290)	11.00 ± 0.08	$7.1^{+3.2}_{-1.7}$ ms	$25.9^{+14.5}_{-9.2}$ ms	$23.2^{+13.2}_{-8.3}$ ms	$8.9^{+5.0}_{-3.3}$ ms	$7.2^{+4.2}_{-2.6}$ ms	[39]
(115,288)	10.61 ± 0.06	87^{+105}_{-30} ms	115^{+48}_{-34} ms	139^{+60}_{-41} ms	43^{+19}_{-13} ms	676^{+279}_{-196} ms	[41]
(115,287)	10.74 ± 0.09	32^{+155}_{-14} ms	55^{+37}_{-22} ms	50^{+34}_{-20} ms	21^{+15}_{-8} ms	131^{+97}_{-55} ms	[41]
(114,289)	9.96 ± 0.06	$2.7^{+1.4}_{-0.7}$ s	$2.8^{+1.3}_{-0.9}$ s	$3.1^{+1.5}_{-1.0}$ s	$1.1^{+0.5}_{-0.3}$ s	$4.8^{+2.5}_{-1.6}$ s	[40]
(114,288)	10.09 ± 0.07	$0.8^{+0.32}_{-0.18}$ s	$1.2^{+0.68}_{-0.43}$ s	$1.12^{+0.63}_{-0.40}$ s	$0.48^{+0.27}_{-0.17}$ s	$0.39^{+0.22}_{-0.14}$ s	[40]
(114,287)	10.16 ± 0.06	$0.48^{+0.16}_{-0.09}$ s	$0.80^{+0.36}_{-0.25}$ s	$0.53^{+0.24}_{-0.17}$ s	$0.32^{+0.15}_{-0.10}$ s	$1.23^{+0.61}_{-0.41}$ s	[39]
(114,286)	10.33 ± 0.06	$0.13^{+0.04}_{-0.02}$ s	$0.29^{+0.13}_{-0.09}$ s	$0.26^{+0.12}_{-0.08}$ s	$0.12^{+0.05}_{-0.04}$ s	$0.10^{+0.04}_{-0.03}$ s	[39]
(113,284)	10.15 ± 0.06	$0.48^{+0.58}_{-0.17}$ s	$0.40^{+0.18}_{-0.12}$ s	$0.50^{+0.23}_{-0.16}$ s	$0.28^{+0.13}_{-0.09}$ s	$2.12^{+0.93}_{-0.64}$ s	[41]
(113,283)	10.26 ± 0.09	100^{+490}_{-45} ms	209^{+152}_{-87} ms	62^{+45}_{-26} ms	91^{+69}_{-39} ms	563^{+445}_{-246} ms	[41]
(113,282)	10.83 ± 0.08	73^{+134}_{-29} ms	8^{+4}_{-3} ms	52^{+30}_{-19} ms	75^{+44}_{-28} ms	52^{+29}_{-18} ms	[42]
(112,285)	9.29 ± 0.06	34^{+17}_{-9} s	50^{+27}_{-17} s	34^{+18}_{-12} s	23^{+12}_{-8} s	133^{+76}_{-48} s	[40]
(112,283)	9.67 ± 0.06	$3.8^{+1.2}_{-0.7}$ s	$3.9^{+1.9}_{-1.3}$ s	$4.5^{+2.2}_{-1.5}$ s	$1.8^{+0.9}_{-0.6}$ s	$8.4^{+4.4}_{-2.9}$ s	[39]
(111,280)	9.87 ± 0.06	$3.6^{+4.3}_{-1.3}$ s	$0.50^{+0.23}_{-0.16}$ s	$3.7^{+1.7}_{-1.2}$ s	$6.0^{+2.9}_{-1.9}$ s	$2.4^{+1.1}_{-0.7}$ s	[41]
(111,279)	10.52 ± 0.16	170^{+810}_{-80} ms	10^{+16}_{-6} ms	62^{+96}_{-37} ms	110^{+177}_{-67} ms	23^{+39}_{-14} ms	[41]
(111,278)	10.89 ± 0.08	$4.2^{+7.5}_{-1.7}$ ms	$1.4^{+0.7}_{-0.5}$ ms	$2.7^{+1.5}_{-0.9}$ ms	$2.7^{+1.6}_{-1.0}$ ms	$8.2^{+4.4}_{-2.9}$ ms	[42]
(110,279)	9.84 ± 0.06	$0.20^{+0.05}_{-0.04}$ s	$0.28^{+0.13}_{-0.09}$ s	$0.18^{+0.08}_{-0.06}$ s	$0.13^{+0.06}_{-0.04}$ s	$0.59^{+0.30}_{-0.20}$ s	[39]
(109,276)	9.85 ± 0.06	$0.72^{+0.97}_{-0.25}$ s	$0.12^{+0.05}_{-0.04}$ s	$0.88^{+0.41}_{-0.28}$ s	$0.29^{+0.14}_{-0.09}$ s	$0.52^{+0.23}_{-0.16}$ s	[41]
(109,275)	10.48 ± 0.09	$9.7^{+46}_{-4.4}$ ms	$3.0^{+2.0}_{-1.2}$ ms	$18.6^{+12.5}_{-7.4}$ ms	$6.7^{+4.6}_{-2.7}$ ms	$6.3^{+4.5}_{-2.6}$ ms	[41]
(109,274)	9.95 ± 0.10	440^{+810}_{-170} ms	67^{+56}_{-30} ms	480^{+416}_{-220} ms	172^{+153}_{-80} ms	353^{+294}_{-159} ms	[42]
(108,275)	9.44 ± 0.06	$0.19^{+0.22}_{-0.07}$ s	$0.75^{+0.36}_{-0.24}$ s	$0.48^{+0.24}_{-0.16}$ s	$0.39^{+0.20}_{-0.13}$ s	$2.12^{+1.12}_{-0.73}$ s	[39]
(107,272)	9.15 ± 0.06	$9.8^{+11.7}_{-3.5}$ s	$2.3^{+1.2}_{-0.8}$ s	$5.3^{+2.8}_{-1.8}$ s	$7.0^{+3.7}_{-2.4}$ s	$8.7^{+4.3}_{-2.9}$ s	[41]
(107,270)	9.11 ± 0.08	61^{+292}_{-28} s	$3.1^{+2.3}_{-1.3}$ s	25^{+19}_{-11} s	60^{+46}_{-26} s	14^{+10}_{-6} s	[42]
(106,271)	8.67 ± 0.08	$1.9^{+2.4}_{-0.6}$ min	$0.51^{+0.41}_{-0.22}$ min	$2.06^{+1.71}_{-0.92}$ min	$1.67^{+1.41}_{-0.76}$ min	$2.28^{+2.01}_{-1.06}$ min	[39]
σ			0.616	0.290	0.238	0.513	

RESULTS

TABLE XII. Theoretical predictions on α-decay lifetimes of superheavy elements. The Q_α values are calculated with the WS4 mass table [44]. The modified and unmodified Viola-Seaborg formulas are represented by VS and VS0, respectively.

Nuclei (Z,A)	Q_α (MeV)	$T_{1/2}^{\mathrm{SW}}$ (s)	$T_{1/2}^{\mathrm{WS}}$ (s)	$T_{1/2}^{\mathrm{EDF}}$ (s)	$T_{1/2}^{\mathrm{VS}}$ (s)	$T_{1/2}^{\mathrm{VS0}}$ (s)
(122,307)	14.360	2.721×10^{-7}	1.417×10^{-7}	3.401×10^{-8}	3.315×10^{-8}	3.402×10^{-8}
(122,306)	13.775	2.641×10^{-6}	1.975×10^{-6}	3.777×10^{-7}	2.380×10^{-7}	2.026×10^{-7}
(122,305)	13.734	3.147×10^{-6}	1.749×10^{-6}	4.746×10^{-7}	5.266×10^{-7}	5.103×10^{-7}
(122,304)	13.710	3.503×10^{-6}	2.684×10^{-6}	5.544×10^{-7}	3.563×10^{-7}	2.669×10^{-7}
(122,303)	13.904	1.630×10^{-6}	9.198×10^{-7}	2.614×10^{-7}	2.468×10^{-7}	2.405×10^{-7}
(122,302)	14.208	5.069×10^{-7}	3.820×10^{-7}	8.078×10^{-8}	4.887×10^{-8}	3.438×10^{-8}
(121,306)	13.783	1.392×10^{-6}	1.396×10^{-6}	1.873×10^{-7}	6.268×10^{-6}	5.896×10^{-6}
(121,305)	13.242	1.296×10^{-5}	1.943×10^{-6}	1.999×10^{-6}	8.881×10^{-6}	8.478×10^{-6}
(121,304)	13.251	1.259×10^{-5}	1.302×10^{-5}	2.030×10^{-6}	6.994×10^{-5}	5.196×10^{-5}
(121,303)	13.283	1.109×10^{-5}	1.673×10^{-6}	1.864×10^{-6}	8.416×10^{-6}	7.039×10^{-6}
(121,302)	13.464	5.247×10^{-6}	5.273×10^{-6}	8.943×10^{-7}	3.391×10^{-5}	2.137×10^{-5}
(121,301)	13.795	1.391×10^{-6}	2.086×10^{-7}	2.344×10^{-7}	9.437×10^{-7}	7.494×10^{-7}

TABLE XIII. Half-lives of nuclides in the decay chain of the nucleus $^{294}117$. The experimental data are from Ref. [49].

(Z,A)	Q_α (MeV)	$T_{1/2}^{\mathrm{Expt.}}$	$T_{1/2}^{\mathrm{SW}}$	$T_{1/2}^{\mathrm{WS}}$	$T_{1/2}^{\mathrm{EDF}}$	$T_{1/2}^{\mathrm{VS}}$	$T_{1/2}^{\mathrm{VS0}}$
(117,294)	11.20 ± 0.04	51^{+94}_{-20} ms	17^{+4}_{-3} ms	34^{+9}_{-7} ms	22^{+6}_{-4} ms	96^{+23}_{-18} ms	75^{+18}_{-14} ms
(115,290)	10.45 ± 0.04	$1.3^{+2.3}_{-0.5}$ s	$0.29^{+0.08}_{-0.06}$ s	$2.0^{+0.56}_{-0.44}$ s	$2.3^{+0.64}_{-0.50}$ s	$1.40^{+0.37}_{-0.29}$ s	$1.28^{+0.33}_{-0.26}$ s
(113,286)	9.4 ± 0.3	$2.9^{+5.3}_{-1.1}$ s	53^{+398}_{-46} s	71^{+552}_{-62} s	24^{+191}_{-21} s	208^{+1452}_{-179} s	209^{+1390}_{-179} s
(111,282)	9.18 ± 0.03	$3.1^{+5.7}_{-1.2}$ min	$0.81^{+0.19}_{-0.16}$ min	$1.91^{+0.46}_{-0.37}$ min	$1.96^{+0.48}_{-0.38}$ min	$2.88^{+0.66}_{-0.54}$ min	$3.60^{+0.81}_{-0.66}$ min
(109,278)	9.59 ± 0.03	$3.6^{+6.5}_{-1.4}$ s	$0.61^{+0.13}_{-0.11}$ s	$4.70^{+1.03}_{-0.84}$ s	$1.44^{+0.32}_{-0.26}$ s	$2.13^{+0.45}_{-0.37}$ s	$3.63^{+0.75}_{-0.62}$ s
(107,274)	8.97 ± 0.03	30^{+54}_{-12} s	$8.0^{+1.9}_{-1.5}$ s	$18.8^{+4.5}_{-3.6}$ s	$22.9^{+5.6}_{-4.5}$ s	$23.6^{+5.5}_{-4.4}$ s	$48.0^{+10.8}_{-8.8}$ s
(105,270)	8.02 ± 0.03	$1.0^{+1.9}_{-0.4}$ h	$0.57^{+0.16}_{-0.12}$ h	$0.82^{+0.23}_{-0.18}$ h	$0.39^{+0.11}_{-0.09}$ h	$1.27^{+0.35}_{-0.27}$ h	$2.91^{+0.78}_{-0.61}$ h
σ			0.769	0.592	0.486	0.773	0.790
			0.625	0.185	0.340	0.173	0.241

Z=117: Tennessine

NEXT STEP - STRATEGY

Y. Lim, YO, PRC 95 (2017)

- Further development on the nuclear α potential based on the Skyrme EDF
- the form of the nuclear α potential

$$V_N = \alpha\rho_N + \beta\left(\rho_n^{5/3} + \rho_p^{5/3}\right) + \gamma\rho_N^{\epsilon}\left(\rho_N^2 + 2\rho_n\rho_p\right) + \delta\frac{\rho_N'}{r} + \eta\rho_N''$$

- Use more sophisticated EDF to obtain the nucleon density profiles in heavy nuclei
- Once the density profiles are obtained, fit the nuclear α potential parameters to the observed α decay data
- Then, apply the model to estimate the unobserved decays.

MODEL SETUP - FITTING PROCESS

- Q_α values: calculated from the observed masses

  E.L. Medeiros, M.M.N. Rodrigues, S.B. Duarte, O.A.P. Tavares, JPG 32, B23 (2006)

$$Q = \Delta M(Z,A) - \Delta M(Z-2, A-4) - \Delta M_\alpha + 10^{-6}\, k \left[Z^\beta - (Z-2)^\beta\right]$$

$$\Delta M_\alpha = 2.4249 \text{ MeV}, \quad k = 8.7 \text{ MeV}, \quad \beta = 2.517 \text{ for } Z \geq 60$$

- Nuclear density profiles - we consider 3 models
  - Skyrme SLy4 E. Chabanat et al., NPA 635, 231 (1998)
  - Gogny D1S J.F. Berger, M. Girod, D. Gogny, Com. Phys. Comm. 63, 365 (1991)
  - RMF DD-ME2 G.A. Lalazissis, T. Niksic, D. Vretenar, P. Ring, PRC 71, 024312 (2005)

EDF MODELS

Skyrme SLy4

$$
\begin{aligned}
v_{ij} = {} & t_0\left(1+x_0 P_\sigma\right)\delta\left(\mathbf{r}_i-\mathbf{r}_j\right) \\
& +\frac{t_1}{2}\left(1+x_1 P_\sigma\right)\left[\delta\left(\mathbf{r}_i-\mathbf{r}_j\right)\mathbf{k}^2+\mathbf{k}'^2\delta\left(\mathbf{r}_i-\mathbf{r}_j\right)\right] \\
& +t_2(1+x_2 P_\sigma)\,\mathbf{k}'\cdot\delta(\mathbf{r}_i-\mathbf{r}_j)\mathbf{k} \\
& +\frac{t_3}{6}\left(1+x_3 P_\sigma\right)\rho^\epsilon\delta(\mathbf{r}_i-\mathbf{r}_j) \\
& +i\,W_0\,\mathbf{k}'\delta(\mathbf{r}_i-\mathbf{r}_j)\times\mathbf{k}\cdot(\boldsymbol{\sigma}_i+\boldsymbol{\sigma}_j)
\end{aligned}
$$

Gogny D1S

$$
\begin{aligned}
v_{12} = {} & \sum_{j=1,2}\exp\left\{-\frac{\left(\mathbf{r}_1-\mathbf{r}_2\right)^2}{\mu_j^2}\right\}\left(W_j+B_jP_\sigma-H_jP_\tau-M_jP_\sigma P_\tau\right) \\
& +t_0\left(1+x_0P_\sigma\right)\rho^\epsilon\left(\frac{\mathbf{r}_1+\mathbf{r}_2}{2}\right)\delta\left(\mathbf{r}_1-\mathbf{r}_2\right) \\
& +iW_{LS}\,\mathbf{k}'\delta\left(\mathbf{r}_1-\mathbf{r}_2\right)\times\mathbf{k}\cdot\left(\boldsymbol{\sigma}_1+\boldsymbol{\sigma}_2\right)
\end{aligned}
$$

RMF DD-ME2

$$
\begin{aligned}
\mathcal{L} = {} & \bar{\psi}\left(i\partial\!\!\!/-m\right)\psi+\frac{1}{2}\partial^\mu\sigma\partial_\mu\sigma-\frac{1}{2}m_\sigma\sigma^2-g_\sigma\bar{\psi}\sigma\psi \\
& -\frac{1}{4}\Omega^{\mu\nu}\Omega_{\mu\nu}+\frac{1}{2}m_\omega^2\omega^2-g_\omega\bar{\psi}\gamma^\mu\omega_\mu\psi \\
& -\frac{1}{4}\vec{R}^{\mu\nu}\cdot\vec{R}_{\mu\nu}+\frac{1}{2}m_\rho^2\vec{\rho}^{\,2}-g_\rho\bar{\psi}\gamma^\mu\vec{\rho}_\mu\cdot\vec{\tau}\psi \\
& -\frac{1}{4}F^{\mu\nu}F_{\mu\nu}-e\bar{\psi}\gamma^\mu A_\mu\frac{(1-\tau_3)}{2}\psi
\end{aligned}
$$

MODEL SETUP – NUCLEAR ALPHA POTENTIAL

TABLE III. Parameters for α particle potential in Eq. (13).

Parameter	SLy4	D1S	DD-ME2	Unit
α	-1484.58	-1499.04	-1524.24	MeV fm^3
β	1355.57	1248.80	1289.04	MeV fm^5
γ	1005.48	242.28	1137.21	MeV fm$^{6+\epsilon}$
δ	53.87	30.75	-41.84	MeV fm^5
η	-210.15	-178.12	-184.09	MeV fm^5
ϵ	$1/6$	$1/3$	$1/6$	

RESULTS – OBSERVED DECAYS

TABLE IV. Observed α decay half-lives of heavy nuclei and the results of the present paper. Unless specified, $\ell = 0$ is understood.

(Z, A)	Q_α^{Expt} (MeV)	$T_{1/2}^{\mathrm{Expt}}$	$T_{1/2}^{\mathrm{SLy4}}(\ell)$	$T_{1/2}^{\mathrm{D1S}}(\ell)$	$T_{1/2}^{\mathrm{DD\text{-}ME2}}(\ell)$	Reference
(118,294)	11.81 $\pm$ 0.06	$0.89^{+1.07}_{-0.31}$ ms	$0.50^{+0.18}_{-0.13}$ ms	$0.61^{+0.22}_{-0.16}$ ms	$0.43^{+0.15}_{-0.11}$ ms	[40]
(116,293)	10.67 $\pm$ 0.06	53^{+62}_{-19} ms	65^{+28}_{-20} ms	78^{+33}_{-23} ms	54^{+24}_{-16} ms	[41]
(116,292)	10.80 $\pm$ 0.07	18^{+16}_{-6} ms	31^{+16}_{-10} ms	38^{+19}_{-13} ms	26^{+13}_{-9} ms	[41]
(116,291)	10.89 $\pm$ 0.07	18^{+22}_{-6} ms	19^{+9}_{-6} ms	23^{+11}_{-7} ms	16^{+8}_{-5} ms	[40]
(116,290)	11.00 $\pm$ 0.08	$7.1^{+3.2}_{-1.7}$ ms	$10.6^{+6.1}_{-3.8}$ ms	$12.5^{+7.2}_{-4.5}$ ms	$8.6^{+5.0}_{-3.1}$ ms	[40]
(115,288)	10.61 $\pm$ 0.06	87^{+105}_{-30} ms	51^{+21}_{-15} ms	57^{+25}_{-17} ms	42^{+19}_{-13} ms	[42,43]
(115,287)	10.74 $\pm$ 0.09	32^{+155}_{-14} ms	25^{+17}_{-10} ms	28^{+20}_{-12} ms	21^{+15}_{-9} ms	[42,43]
(114,289)	9.96 $\pm$ 0.06	$2.7^{+1.4}_{-0.7}$ s	$1.3^{+0.6}_{-0.4}$ s	$1.5^{+0.7}_{-0.5}$ s	$1.0^{+0.5}_{-0.3}$ s	[41]
(114,288)	10.09 $\pm$ 0.07	$0.8^{+0.32}_{-0.18}$ s	$0.56^{+0.31}_{-0.20}$ s	$0.65^{+0.37}_{-0.23}$ s	$0.46^{+0.26}_{-0.16}$ s	[41]
(114,287)	10.16 $\pm$ 0.06	$0.48^{+0.16}_{-0.09}$ s	$0.37^{+0.17}_{-0.12}$ s	$0.42^{+0.20}_{-0.13}$ s	$0.31^{+0.15}_{-0.10}$ s	[40]
(114,286)	10.33 $\pm$ 0.06	$0.13^{+0.04}_{-0.02}$ s	$0.14^{+0.06}_{-0.04}$ s	$0.15^{+0.07}_{-0.05}$ s	$0.12^{+0.05}_{-0.04}$ s	[40]
(113,284)	10.15 $\pm$ 0.06	$0.48^{+0.58}_{-0.17}$ s	$0.20^{+0.09}_{-0.06}$ s	$0.23^{+0.10}_{-0.07}$ s	$0.28^{+0.13}_{-0.09}$ s ($\ell = 2$)	[42,43]
(113,283)	10.26 $\pm$ 0.09	100^{+490}_{-45} ms	106^{+77}_{-45} ms	120^{+89}_{-51} ms	94^{+70}_{-40} ms	[42,43]
(113,282)	10.83 $\pm$ 0.08	73^{+134}_{-29} ms	106^{+62}_{-38} ms ($\ell = 6$)	121^{+73}_{-45} ms ($\ell = 6$)	93^{+55}_{-34} ms ($\ell = 6$)	[44]
(112,285)	9.29 $\pm$ 0.06	34^{+17}_{-9} s	27^{+14}_{-10} ms	30^{+16}_{-10} s	22^{+13}_{-8} s	[41]
(112,283)	9.67 $\pm$ 0.06	$3.8^{+1.2}_{-0.7}$ s	$2.0^{+1.0}_{-0.7}$ s	$2.3^{+1.2}_{-0.8}$ s	$1.8^{+0.9}_{-0.6}$ s	[40]
(111,280)	9.87 $\pm$ 0.06	$3.6^{+4.3}_{-1.3}$ s	$1.4^{+0.7}_{-0.4}$ s ($\ell = 4$)	$1.6^{+0.8}_{-0.5}$ s ($\ell = 4$)	$7.2^{+3.4}_{-2.3}$ s ($\ell = 6$)	[42,43]
(111,279)	10.52 $\pm$ 0.16	170^{+810}_{-80} ms	157^{+251}_{-95} ms ($\ell = 6$)	176^{+276}_{-106} ms ($\ell = 6$)	138^{+219}_{-83} ms ($\ell = 6$)	[42,43]
(111,278)	10.89 $\pm$ 0.08	$4.2^{+7.5}_{-1.7}$ ms	$3.5^{+1.9}_{-1.3}$ ms ($\ell = 4$)	$3.9^{+2.2}_{-1.4}$ ms ($\ell = 4$)	$3.2^{+1.8}_{-1.1}$ ms ($\ell = 4$)	[44]
(110,279)	9.84 $\pm$ 0.06	$0.20^{+0.05}_{-0.04}$ s	$0.15^{+0.07}_{-0.05}$ s	$0.17^{+0.08}_{-0.05}$ s	$0.13^{+0.06}_{-0.04}$ s	[40]
(109,276)	9.85 $\pm$ 0.06	$0.72^{+0.97}_{-0.25}$ s	$0.37^{+0.17}_{-0.12}$ s ($\ell = 4$)	$0.41^{+0.19}_{-0.13}$ s ($\ell = 4$)	$0.33^{+0.16}_{-0.10}$ s ($\ell = 4$)	[42,43]
(109,275)	10.48 $\pm$ 0.09	$9.7^{+46}_{-4.4}$ ms	$8.7^{+5.9}_{-3.5}$ ms ($\ell = 4$)	$9.4^{+6.6}_{-3.8}$ ms ($\ell = 4$)	$7.9^{+5.4}_{-3.2}$ ms ($\ell = 4$)	[42,43]
(109,274)	9.95 $\pm$ 0.10	440^{+810}_{-170} ms	220^{+195}_{-99} ms ($\ell = 4$)	242^{+211}_{-112} ms ($\ell = 4$)	200^{+170}_{-94} ms ($\ell = 4$)	[44]
(108,275)	9.44 $\pm$ 0.06	$0.19^{+0.22}_{-0.07}$ s	$0.46^{+0.23}_{-0.15}$ s	$0.51^{+0.25}_{-0.17}$ s	$0.42^{+0.21}_{-0.14}$ s	[40]
(107,272)	9.15 $\pm$ 0.06	$9.8^{+11.7}_{-3.5}$ s	$9.0^{+4.7}_{-3.1}$ s ($\ell = 4$)	$9.7^{+5.1}_{-3.3}$ s ($\ell = 4$)	$7.9^{+4.1}_{-2.7}$ s ($\ell = 4$)	[42,43]
(107,270)	9.11 $\pm$ 0.08	61^{+292}_{-28} s	73^{+58}_{-30} s ($\ell = 6$)	84^{+64}_{-36} s ($\ell = 6$)	70^{+54}_{-30} s ($\ell = 6$)	[44]
(106,271)	8.67 $\pm$ 0.08	$1.9^{+2.4}_{-0.6}$ min	$2.10^{+1.77}_{-0.95}$ min ($\ell = 4$)	$2.27^{+1.99}_{-1.02}$ min ($\ell = 4$)	$1.83^{+1.54}_{-0.83}$ min ($\ell = 4$)	[40]
RMSD			0.209	0.198	0.218	

PREDICTIONS FOR UNOBSERVED DECAYS

- Q_α values: need a model for nuclear masses
  - modified Liquid Droplet Model (LDM)

W.D. Myers, W.J. Swiatecki, Ann. Phys. 55, 395 (1969)
A.W. Steiner, M. Prakash, J.M. Lattimer, P.J. Ellis, Phys. Rep. 411, 325 (2005)

$$E = f_B\,(A - N_s) + 4\pi R^2 \sigma(\mu_n) + \mu_n N_s + E_{\rm Coul} + E_{\rm pair} + E_{\rm shell},$$

f_B : binding energy per baryon in infinite nuclear matter

N_s : number of neutrons in the neutron skin

σ surface tension

$E_{\rm Coul}$: Coulomb energy

$E_{\rm paor}$: pairing energy

$E_{\rm shell}$: shell corrections

D.G. Ravenhall et al., NPA 407, 571 (1983)
J. Duflo, A.P. Zuker, PRC 52, R23 (1995)
A.E.L. Dieperink, P. Van Isacker, EPJA 42, 269 (2009)

Parameters are fitted by nuclear masses: Global fitting

PREDICTIONS FOR UNOBSERVED DECAYS

- Local formula for the Q_α values
  - Taylor expansion of the Q_α formula for heavy nuclei (large N and Z)

J. Dong, W. Zuo, J. Gu, Y. Wang, B. Peng, PRC 81, 064309 (2010)
T. Dong, Z. Rev, PRC 77, 064310 (2008)

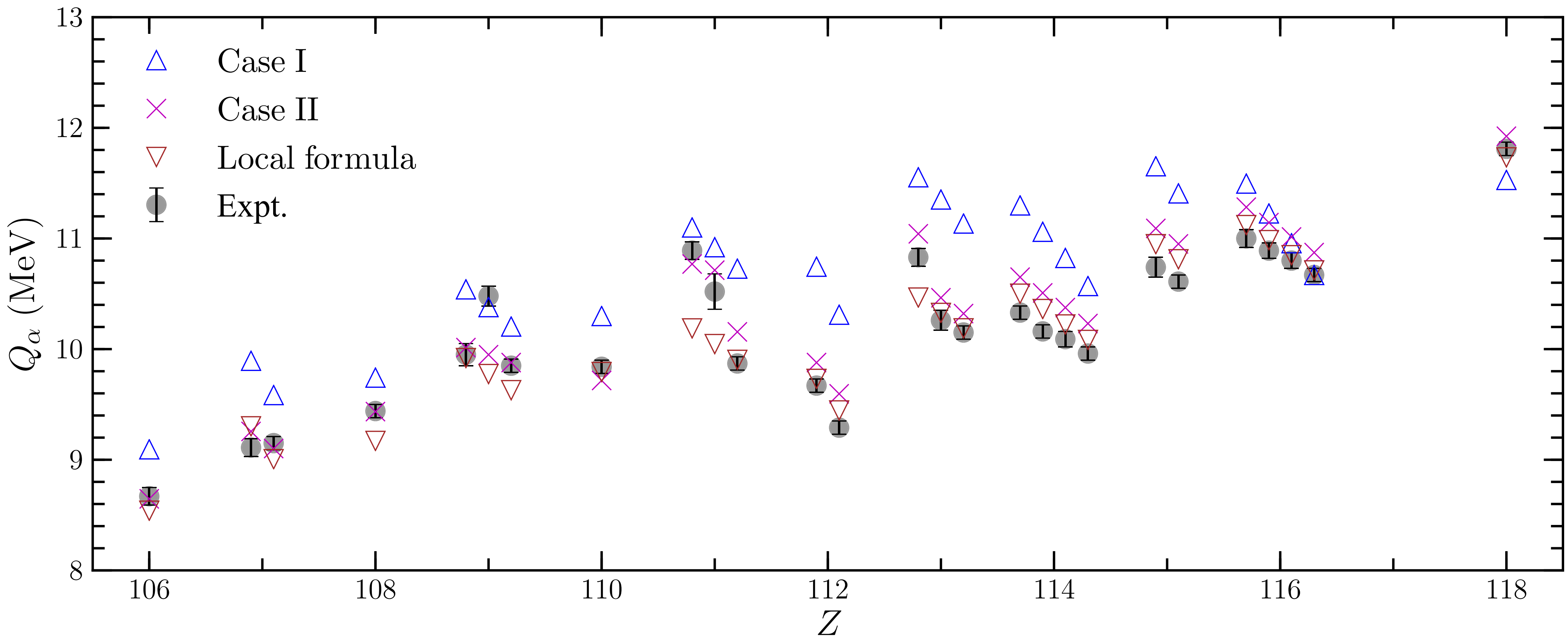
$$Q = a\frac{Z}{A^{4/3}}(3A - Z) + b\left(\frac{N-Z}{A}\right)^2 + c\left[\frac{|N-152|}{N} - \frac{|N-154|}{N-2}\right] + d\left[\frac{|Z-110|}{Z} - \frac{|Z-112|}{Z-2}\right] + e,$$

TABLE II. The best-fit parameters of Eq. (11). All parameters have a unit of MeV.

a	b	c	d	e	RMSD
0.90753	−97.84028	16.15924	−18.95722	−26.16600	0.255

$$Z \geq 90, \quad N \geq 140$$

COMPARISON – Q VALUES



Case I, Case II: two parameter sets for LDM

COMPARISON – ALPHA POTENTIAL

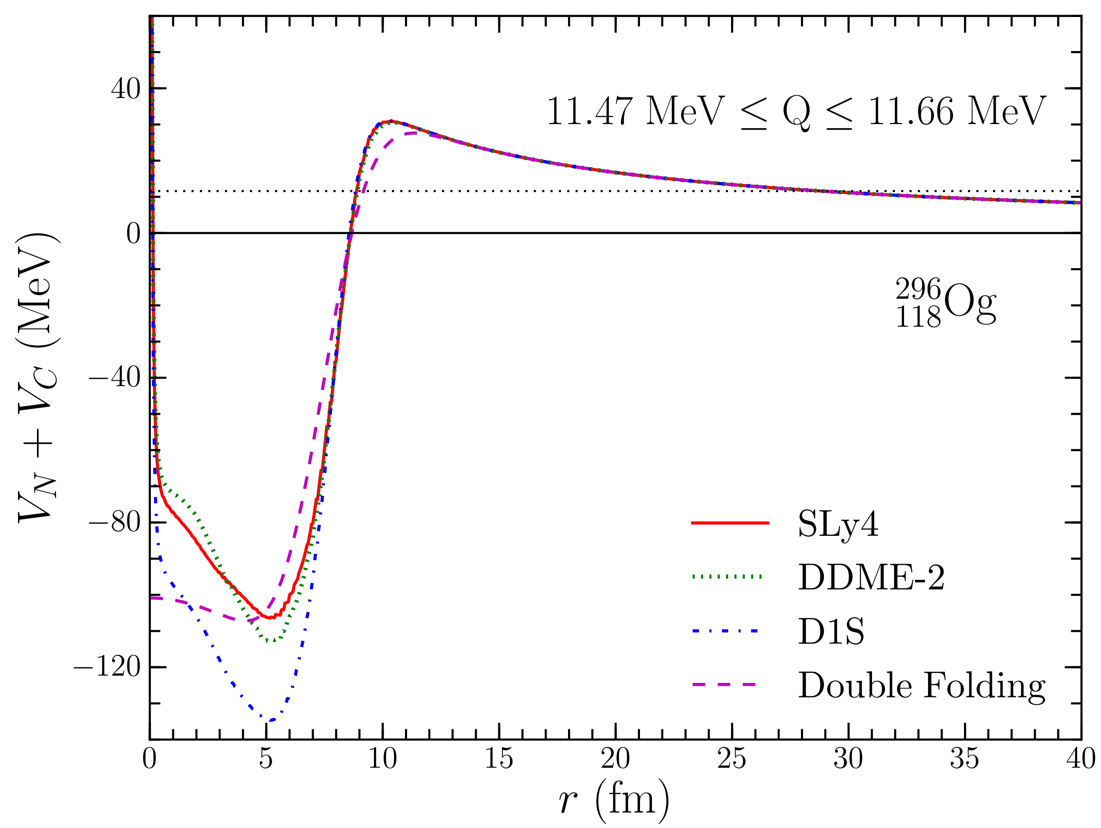


FIG. 3. The α nuclear and Coulomb potentials, $V_N + V_C$, for $^{296}_{118}$Og in the models of the present paper. The double folding potential for $^{296}_{118}$Og of Ref. [47] is also presented for comparison.

Double Folding Model

P. Mohr, PRC 95, 011302(R) (2017)

PREDICTIONS

TABLE V. Predictions on the α decay lifetimes for unobserved superheavy elements with Q values from the LDM (case II) and from the local formula.

Nuclei (Z, A)	Q (MeV) LDM	$T_{1/2}^{\text{SLy4}}$ (s)	$T_{1/2}^{\text{D1S}}$ (s)	$T_{1/2}^{\text{DD-ME2}}$ (s)	Q (MeV) Local formula	$T_{1/2}^{\text{SLy4}}$ (s)	$T_{1/2}^{\text{D1S}}$ (s)	$T_{1/2}^{\text{DD-ME2}}$ (s)
(122, 307)	12.594	9.467×10^{-5}	9.982×10^{-5}	6.999×10^{-5}	12.289	4.340×10^{-4}	4.514×10^{-4}	3.194×10^{-4}
(122, 306)	12.729	5.649×10^{-5}	5.836×10^{-5}	4.183×10^{-5}	12.420	2.517×10^{-4}	2.688×10^{-4}	1.891×10^{-4}
(122, 305)	12.853	3.334×10^{-5}	3.607×10^{-5}	2.525×10^{-5}	12.550	1.402×10^{-4}	1.539×10^{-4}	1.073×10^{-4}
(122, 304)	12.986	1.931×10^{-5}	2.100×10^{-5}	1.480×10^{-5}	12.679	7.919×10^{-5}	8.911×10^{-5}	6.193×10^{-5}
(122, 303)	13.108	1.145×10^{-5}	1.300×10^{-5}	9.047×10^{-6}	12.807	4.646×10^{-5}	5.237×10^{-5}	3.593×10^{-5}
(122, 302)	13.239	6.692×10^{-6}	7.539×10^{-6}	5.339×10^{-6}	12.935	2.646×10^{-5}	3.000×10^{-5}	2.099×10^{-5}
(121, 306)	12.114	5.360×10^{-4}	5.522×10^{-4}	3.846×10^{-4}	11.853	2.104×10^{-3}	2.175×10^{-3}	1.509×10^{-3}
(121, 305)	12.250	2.948×10^{-4}	3.093×10^{-4}	2.170×10^{-4}	11.985	1.143×10^{-3}	1.212×10^{-3}	8.467×10^{-4}
(121, 304)	12.367	1.664×10^{-4}	1.831×10^{-4}	1.274×10^{-4}	12.117	6.082×10^{-4}	6.787×10^{-4}	4.700×10^{-4}
(121, 303)	12.511	9.077×10^{-5}	1.030×10^{-4}	7.119×10^{-5}	12.248	3.317×10^{-4}	3.794×10^{-4}	2.593×10^{-4}
(121, 302)	12.636	5.323×10^{-5}	6.026×10^{-5}	4.191×10^{-5}	12.378	1.834×10^{-4}	2.093×10^{-4}	1.439×10^{-4}
(121, 301)	12.769	2.976×10^{-5}	3.401×10^{-5}	2.378×10^{-5}	12.508	1.027×10^{-4}	1.169×10^{-4}	8.201×10^{-5}
(120, 304)	11.790	1.567×10^{-3}	1.650×10^{-3}	1.167×10^{-3}	11.546	5.792×10^{-3}	6.146×10^{-3}	4.349×10^{-3}
(120, 303)	11.918	8.584×10^{-4}	9.358×10^{-4}	6.494×10^{-4}	11.679	2.987×10^{-3}	3.331×10^{-3}	2.289×10^{-3}
(120, 302)	12.055	4.456×10^{-4}	5.025×10^{-4}	3.459×10^{-4}	11.812	1.561×10^{-3}	1.761×10^{-3}	1.217×10^{-3}
(120, 301)	12.181	2.491×10^{-4}	2.816×10^{-4}	1.959×10^{-4}	11.944	8.288×10^{-4}	9.395×10^{-4}	6.575×10^{-4}
(120, 300)	12.317	1.342×10^{-4}	1.523×10^{-4}	1.068×10^{-4}	12.076	4.465×10^{-4}	5.053×10^{-4}	3.520×10^{-4}
(120, 299)	12.442	7.735×10^{-5}	8.978×10^{-5}	6.175×10^{-5}	12.207	2.436×10^{-4}	2.817×10^{-4}	1.957×10^{-4}
(119, 298)	11.973	4.022×10^{-4}	4.688×10^{-4}	3.243×10^{-4}	11.772	1.131×10^{-3}	1.322×10^{-3}	8.986×10^{-4}
(119, 297)	12.109	2.119×10^{-4}	2.415×10^{-4}	1.706×10^{-4}	11.904	5.932×10^{-4}	1.610×10^{-3}	4.795×10^{-4}
(119, 296)	12.234	1.181×10^{-4}	1.340×10^{-4}	9.719×10^{-5}	12.036	3.147×10^{-4}	3.587×10^{-4}	2.593×10^{-4}
(119, 295)	12.368	6.172×10^{-5}	7.814×10^{-5}	5.316×10^{-5}	12.167	1.643×10^{-4}	1.913×10^{-4}	1.405×10^{-4}
(119, 294)	12.492	3.425×10^{-5}	4.112×10^{-5}	2.983×10^{-5}	12.297	8.668×10^{-5}	1.044×10^{-4}	7.549×10^{-5}
(119, 293)	12.625	1.874×10^{-5}	2.264×10^{-5}	1.646×10^{-5}	12.427	4.775×10^{-5}	5.767×10^{-5}	4.168×10^{-5}
(118, 298)	11.393	4.077×10^{-3}	4.600×10^{-3}	3.215×10^{-3}	11.197	1.206×10^{-2}	1.373×10^{-2}	9.535×10^{-3}
(118, 297)	11.522	2.126×10^{-3}	2.488×10^{-3}	1.699×10^{-3}	11.332	5.977×10^{-3}	7.008×10^{-3}	4.774×10^{-3}
(118, 296)	11.660	1.068×10^{-3}	1.238×10^{-3}	8.599×10^{-4}	11.466	3.013×10^{-3}	3.481×10^{-3}	2.423×10^{-3}
(118, 295)	11.787	5.640×10^{-4}	6.577×10^{-4}	4.692×10^{-4}	11.600	1.500×10^{-3}	1.762×10^{-3}	1.244×10^{-3}
(118, 294)	11.924	2.824×10^{-4}	8.069×10^{-4}	2.412×10^{-4}	11.733	7.515×10^{-4}	9.050×10^{-4}	6.387×10^{-4}
(118, 293)	12.050	1.516×10^{-4}	1.835×10^{-4}	1.305×10^{-4}	11.865	3.832×10^{-4}	4.644×10^{-4}	3.289×10^{-4}
(117, 298)	10.779	6.202×10^{-2}	7.032×10^{-2}	4.795×10^{-2}	10.920	1.678×10^{-1}	1.916×10^{-1}	1.311×10^{-1}
(117, 297)	10.920	2.837×10^{-2}	3.274×10^{-2}	2.236×10^{-2}	10.749	7.769×10^{-2}	9.001×10^{-2}	6.129×10^{-2}
(117, 296)	11.051	1.409×10^{-2}	1.666×10^{-2}	1.126×10^{-2}	10.886	3.620×10^{-2}	4.330×10^{-2}	2.903×10^{-2}
(117, 295)	11.192	6.660×10^{-3}	7.806×10^{-3}	5.400×10^{-3}	11.023	1.735×10^{-2}	2.035×10^{-2}	1.396×10^{-2}
(117, 294)	11.321	3.310×10^{-3}	3.965×10^{-3}	6.634×10^{-3}	11.158	8.146×10^{-3}	9.736×10^{-3}	6.779×10^{-3}
(117, 293)	11.460	1.584×10^{-3}	1.941×10^{-3}	1.325×10^{-3}	11.293	3.885×10^{-3}	4.752×10^{-3}	3.244×10^{-3}

PREDICTIONS

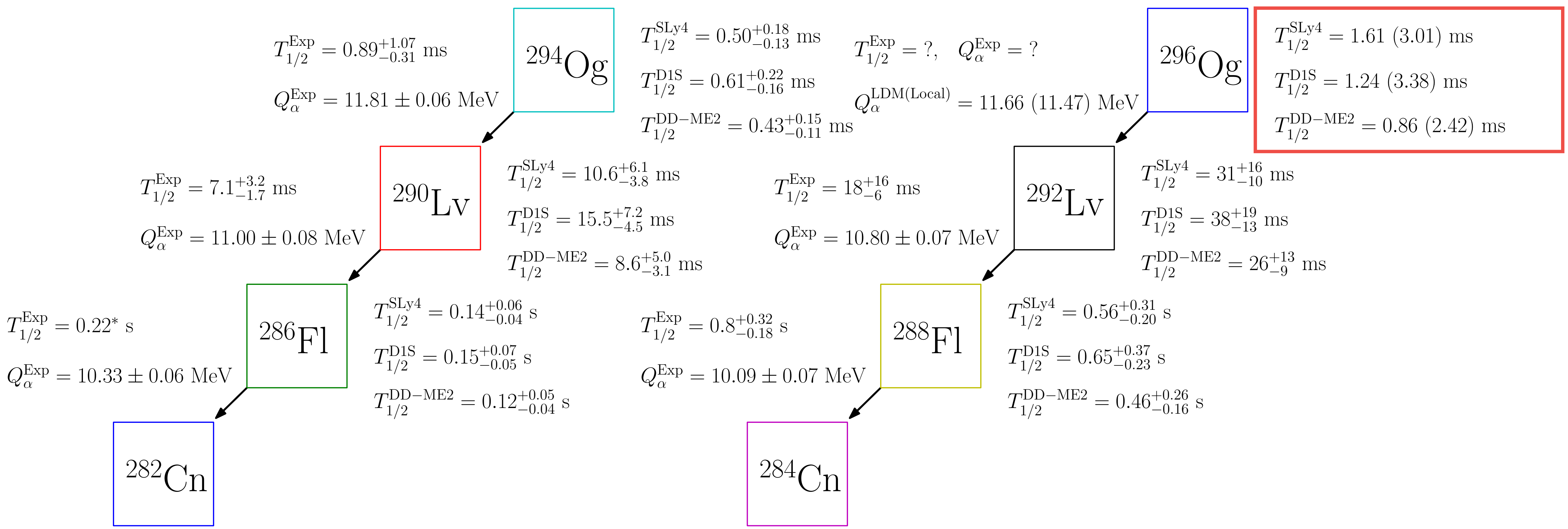


FIG. 2. Float charts for α decay chains for $^{294}_{118}$Og and $^{296}_{118}$Og. The measured half-life of $^{286}_{114}$Fl is about 0.13 s. Since the branching ratio of its α decay is about 60% [45,46], however, the half-life of its α decay is about 0.22 s.

For ^{296}Og

Our prediction: $0.86 \sim 3.48$ ms

0.5 ~ 4.8 ms: A. Sobiczewski, PRC 94, 051302(R) (2016)

0.825 ms: P. Mohr, PRC 95, 011302(R) (2017)

Planned to measure at JINR

CONCLUSIONS & OUTLOOK

- To develop more realistic theories on the nuclear α decay.
  - simple potential models
  - based on EDF
- Other elements
  - deformation
  - direct calculation using α cluster models
  - other theoretical framework